EFFECT ON CERTAIN FRESH FRUITS OF FUMIGATION WITH ETHYLENE OXIDE TO DESTROY THE JAPANESE BEETLE[1]

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Abstract

Ethylene oxide is used at the rate of 2 pounds per 1,000 cubic feet for two hours at 75° F. destroyed adults and larvæ of the Japanese beetle, adult Colorado potato beetles, and adult Mexican bean beetles.

Ethylene oxide may be used as herein described without any appreciable damage to raspberries and blackberries, but is slightly injurious to blueberries and severely injures wet green bananas.

When used at the rate herein mentioned, ethylene oxide is injurious to the foliage of Azalea and Hydrangea.

Since the development of a method for fumigating fresh fruit with carbon disulphide[2] to destroy the adult Japanese beetle, experiments have been underway to develop a fumigant for this purpose which would be equally effective as an insecticide and as non-injurious to the fruit, but which in addition would be less inflammable and explosive than carbon disulphide. The preliminary experiments with different compounds indicated that ethylene oxide, a chemical whose insecticidal properties were discovered by Cotton and Roark[3] might be substituted for carbon disulphide for this purpose.

Cotton and Roark have shown that a dosage of 1 pound per 1,000 cubic feet of space for 20 hours proved to be 100 per cent

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[2] Osburn, M. R. Fumigation of fresh fruit with carbon disulphide for the destruction of adult Japanese beetles, N. J. Dept. Agr. Circ. 188, 1930.

[3] Cotton, R. T., and Roark, R. C. Ethylene oxide as a fumigant. Ind. and Eng. Chem. 20: 805, Aug., 1928.

lethal to specimens of the webbing clothes moth, *Tineola biselliella* Hum.; the black carpet beetle, *Attagenus piceus* Oliv., and the furniture carpet beetle, *Anthrenus vorax* Csy.; the rice weevil, *Sitophilus oryza* L.; the Indian meal moth, *Plodia interpunctella* Hbn.; the saw-toothed grain beetle, *Oryzæphilus surinamensis* L.; the red-legged ham beetle, *Necrobia rufipes* DeG.; and the confused flour beetle, *Tribolium confusum* Duv.

Ethylene oxide, according to Back, Cotton, and Ellington,[4] has been used as a fumigant with success in destroying infestations of the webbing clothes moth, the furniture carpet beetle, the confused flour beetle, the rice weevil, and the saw-toothed grain beetle.

Properties of Ethylene Oxide

The physical properties of ethylene oxide have been described recently by Back, Cotton and Ellington[5] and Roark and Nelson.[6]

It is at ordinary temperatures a colorless gas; at low temperatures, it is a mobile colorless liquid boiling at 10.5° C. The specific gravity of liquid ethylene oxide is 0.887 at 7°/4° C. The empirical formula is C_2H_4O. The molecular weight is 44.031. The concentrated vapors of ethylene oxide are inflammable, but concentrations up to 3½ pounds per 1,000 cubic feet of space are non-explosive and non-inflammable. The ignition point is 814° F. Ethylene oxide has a faint but distinct ether-like odor and the vapor is approximately 1.7 times as heavy as air. The vapor exhibits remarkable penetration into such compact materials as soil. The vapor of ethylene oxide, while not highly toxic to man, should not be inhaled extensively.

Effectiveness of Ethylene Oxide as a Fumigant

The effect of ethylene oxide as a fumigant for fresh fruit was determined in a fumigation house of 1,000 cubic feet capacity,

[4] Back, E. A., Cotton, R. T., and Ellington, G. W. Ethylene oxide as a fumigant for food and other commodities. Jour. Econ. Ent. 23: 226, Feb., 1930.

[5] Back, E. A., Cotton, R. T., and Ellington, G. W. Ethylene oxide as a fumigant for food and other commodities. Jour. Econ. Ent. 23: 226, Feb., 1930.

[6] Roark, R. C., and Nelson, O. A. Densities of mixtures of air and various fumigants. Jour. Econ. Ent. 23: 985–987, Dec., 1930.

10 feet long, 10 feet wide, and 10 feet high. It has a door in front and a window in the rear. It is gas-tight, being double walled throughout, with two-ply roofing paper between the walls, and lined on the inside with galvanized iron sheets, soldered together. The door and window are made tight by closing on metal strips. A hot-water heating system of 40 gallons' capacity, thermostatically controlled, was used to maintain the desired temperature. An electric fan, having its motor placed on the outside of the fumigation room, was used to circulate the vapor.

In the summer of 1930, some 16,000 adult Japanese beetles were fumigated, under varying conditions, with ethylene oxide to determine the best conditions for killing 100 per cent of them. In one series of tests, beetles were exposed directly to the vapor in rectangular cages 24 inches long, 11 inches wide, and 14 inches high. The sides and tops of these were covered with wire screen and each was provided with a door. In another series of tests, the beetles were treated while contained in baskets of fruit. Immediately before treatment, several boxes placed in various parts of each layer of a crate of fruit were artificially infested with beetles.

In connection with these experiments adults of the Colorado potato beetle (*Leptinotarsa decemlineata* Say) and the Mexican bean beetle (*Epilachna corrupta* Muls.), contained in rectangular wire-screen cages as described above, were exposed directly to the vapor of ethylene oxide, to determine conditions for killing 100 per cent. A comparison was made simultaneously of conditions necessary for killing 100 per cent of Japanese beetle larvæ exposed directly to the vapor of ethylene oxide in cross-section wire-screen cages, and for killing 100 per cent of Japanese beetle larvæ exposed to the gas when buried in the soil in 6-inch and 14-inch flowerpots.

In the various experiments, the insects were placed in the fumigation house as soon as the desired temperature was reached. In each experiment, the proper dosage of ethylene oxide was measured as a liquid and poured into shallow pans that rested on a table. The window and door of the house were closed and made tight. The fan was started to circulate the ethylene oxide

vapor, which evolves rapidly at ordinary fumigation temperatures. After the desired time had elapsed, the door and window were thrown open to ventilate the room. As soon afterwards as possible the treated insects, with the exception of Japanese beetle larvæ, were taken to the insectary, where they were examined, at the end of 24 and 48 hours, to determine the number that were alive or dead. The Japanese beetle larvæ were removed from the cages and soil immediately after treatment and placed on soil in wooden cross-sectioned trays. This procedure made it possible for any larvæ which had not been harmed by the treatment to go into the soil under normal conditions. At the end of five days all the larvæ were examined to determine the number dead or alive. For comparison, untreated insects were held in the same manner.

TEMPERATURE, EXPOSURE, DOSAGE

It was found that when adult Japanese beetles were exposed for two hours to the vapor of 1 pound of ethylene oxide to 1,000 cubic feet of space, 90 per cent of them were killed at a temperature of 65° F., 96 per cent at 70°, and 100 per cent at 75°. One pound for one hour killed 54 per cent at 75° and 93 per cent at 80°. When ethylene oxide was used at the rate of 2 pounds per 1,000 cubic feet 96 per cent of the beetles were destroyed at the end of one hour at a temperature of 75° and all of the beetles were destroyed when the temperature was raised to 80° or the period of exposure was prolonged to two hours.

Experiments in which beetles were fumigated in boxes of fresh fruit showed that it was necessary to use 2 pounds of ethylene oxide per 1,000 cubic feet of space for a period of two hours at 75° F. to obtain a 100 per cent mortality.

Potato beetles were more easily killed than adult Japanese beetles since a dosage of 1 pound per 1,000 cubic feet at 70° destroyed all the potato beetles in a period of two hours but killed only 96 per cent of the Japanese beetles.

Adult Mexican bean beetles were easier to kill than either potato beetles or Japanese beetles, for a dosage of 1 pound per 1,000 cubic feet at 60° for two hours destroyed 100 per cent, while higher temperatures were necessary for a complete kill of potato beetles and Japanese beetles.

Japanese beetle larvæ were not so easy to destroy as the adults since it was necessary to use 1 pound per 1,000 cubic feet for two hours at 75° to kill all the larvæ, while all Japanese beetle adults were destroyed at 70°.

Experiments with ethylene oxide as a soil fumigant to destroy Japanese beetle larvæ showed that when soil balls each 6 inches in diameter were treated at 80° F. a concentration of 2 pounds per 1,000 cubic feet for three hours destroyed all the larvæ buried in them, and 7½ pounds for two hours killed 100 per cent. Similar tests with soil balls of 14-inch diameter showed that all larvæ buried in them were destroyed when the balls were exposed to 10 pounds of ethylene oxide per 1,000 cubic feet at 80° for three hours.

A summary of the various tests is outlined in charts 1, 3, 4, 6, and 7.

THE EFFECT OF ETHYLENE OXIDE ON CERTAIN FRUITS

In the summer of 1930, raspberries, blackberries, and blueberries were fumigated with ethylene oxide at the rate of 2 pounds to 1,000 cubic feet of space for two hours at temperatures of 75° and 80° F., respectively. All fruits were treated immediately after they were received at the laboratory. The fruits thus used were as follows:

Fruits	*Variety*	*Quantity*
Blueberries	Rubel	32 quarts
Blueberries	Grover	32 quarts
Raspberries		936 pints
Blackberries		1,600 quarts
Bananas		30 hands

Upon completion of the treatment all of this fruit except the blueberries was taken from the fumigation chamber and held at outside temperatures together with a representative quantity of untreated fruit of the same varieties for at least 48 hours to determine the effect of the treatments. The blueberries were sent to R. B. Wilcox, Assistant Plant Pathologist, Toms River, New Jersey, who determined the effect of the treatment according to a system devised by the Bureau of Plant Industry, U. S. Department of Agriculture, in which the berries were placed in an incubator at 86° F. for a period of six days and then the

condition of the treated fruit was compared with that of the untreated. Raspberries and blackberries were apparently uninjured by the treatment, while the treated blueberries were slightly inferior to the untreated. A comparison based on the firmness of the raspberries and blackberries treated with ethylene oxide and the firmness of those untreated is shown in chart 2. The results with blueberries are shown in chart 5.

EFFECT OF ETHYLENE OXIDE ON WET BANANAS

Conditions at the port of Philadelphia make it necessary to fumigate railway fruit cars containing wet, green bananas. In view of the possibility of using ethylene oxide as the fumigant for this work, wet green bananas were exposed to 2 pounds of ethylene oxide per 1,000 cubic feet of space at 75° F. for two hours.

It was found that this treatment caused such extensive damage to the fruit that it would not be advisable to use ethylene oxide as the fumigating material.

EFFECT OF ETHYLENE OXIDE ON GROWING PLANTS

As preliminary experiments, two varieties of *Azalea indica, viz.,* Mme. Vandercruyssen and Mme. Petrick, and one variety of *Hydrangea opuloides,* namely, Mme. Chautard, were exposed to the vapor of 2 pounds of ethylene oxide per 1,000 cubic feet for two hours at 75° F. The plants were severely injured by the treatment, and the foliage turned black, curled, and fell in a few days.

PLATE XXXXII

Chart 1. Fumigation of Japanese beetle larvæ exposed directly to the vapor of ethylene oxide. Dosages were for 1,000 cubic feet.

Chart 2. Proportions of fruits that were firm after treatment with 2 pounds of ethylene oxide per 1,000 cubic feet for two hours at 75 and 80 degrees Fahrenheit, compared with the proportions of untreated fruits that were firm.

Chart 3. Fumigation of potato beetles with ethylene oxide for 2 hours. Dosages were for 1,000 cubic feet.

Chart 4. Fumigation of Mexican bean beetles with ethylene oxide. Dosages were for 1,000 cubic feet.

Chart 5. Blueberries that were treated with 2 pounds of ethylene oxide for two hours at 75 degrees Fahrenheit compared with untreated berries.

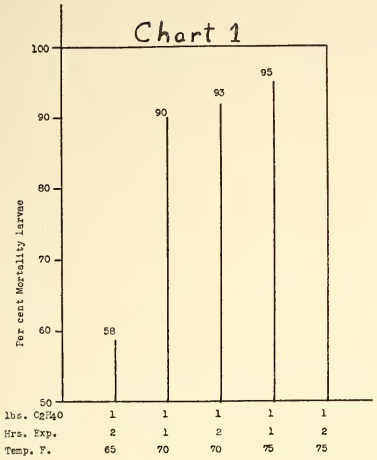
Chart 1
Per cent Mortality larvae
100
90
80
70
60
50
58
90
93
95
lbs. C2H4O 1 1 1 1 1
Hrs. Exp. 2 1 2 1 2
Temp. F. 65 70 70 75 75

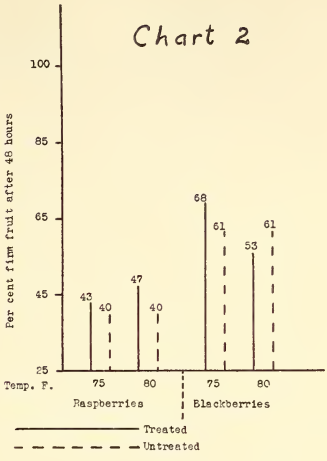
Chart 2
Per cent firm fruit after 48 hours
100
85
65
45
25
43
40
47
40
68
61
53
61
Temp. F. 75 80 75 80
Raspberries
Blackberries
Treated
Untreated

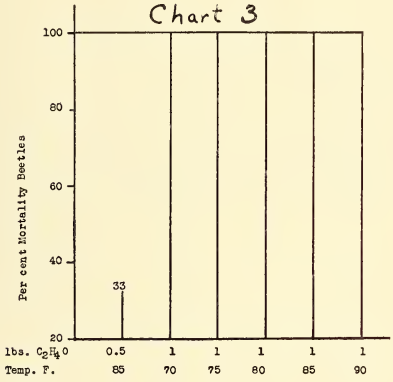
Chart 3
Per cent Mortality Beetles
100
80
60
40
20
33
lbs. C2H4O 0.5 1 1 1 1 1
Temp. F. 85 70 75 80 85 90

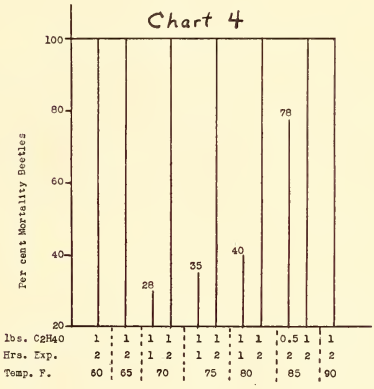
Chart 4
Per cent Mortality Beetles
100
80
60
40
20
28
35
40
78
lbs. C2H4O 1 1 1 1 1 1 1 1 1 0.5 1 1
Hrs. Exp. 2 2 1 2 1 2 1 2 1 2 2 2
Temp. F. 60 65 70 75 80 85 90

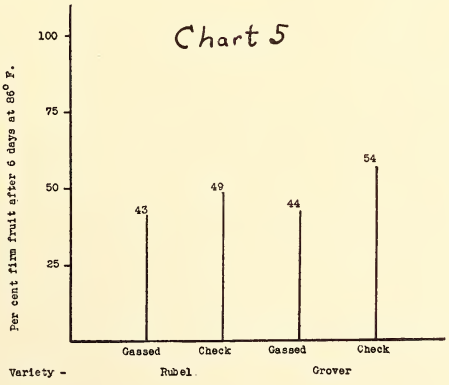
Chart 5
Per cent firm fruit after 6 days at 86° F.
100
75
50
25
43
49
44
54
Gassed
Check
Gassed
Check
Variety - Rubel Grover

PLATE XXXXIII

Chart 6. Fumigation of adult Japanese beetles with ethylene oxide. Dosages were for 1,000 cubic feet.

Chart 7. Fumigation of soil containing Japanese beetle larvæ with ethylene oxide at 80° F. Dosages were for 1,000 cubic feet.

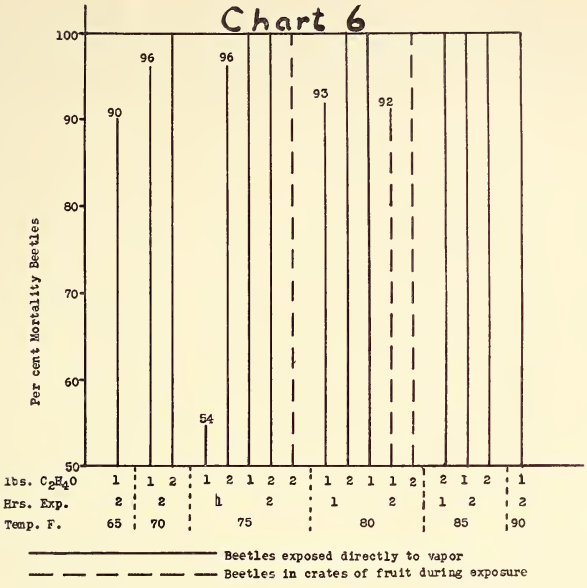
Chart 6
Per cent Mortality Beetles
100
90
80
70
60
50
90
96
54
96
93
92
lbs. C_2H_4O 1 1 2 1 2 1 2 2 1 2 1 1 2 2 1 2 1
Hrs. Exp. 2 2 4 2 1 2 2
Temp. F. 65 70 75 80 85 90
Beetles exposed directly to vapor
Beetles in crates of fruit during exposure

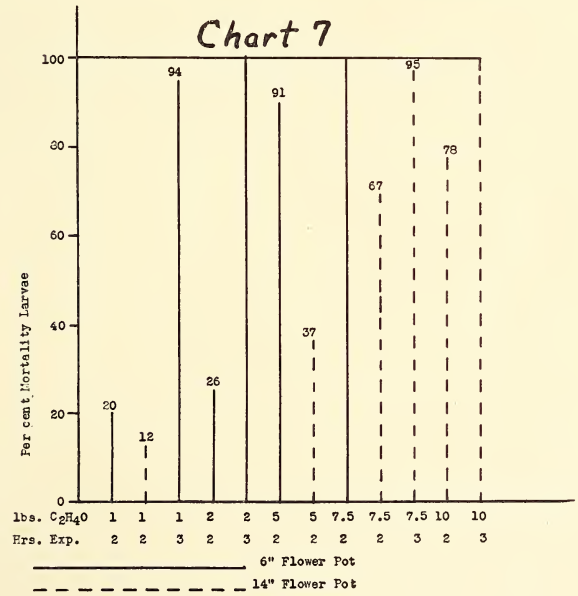
Chart 7
Per cent Mortality Larvae
100
80
60
40
20
0
20
12
94
26
91
37
67
95
78
lbs. C_2H_4O 1 1 1 2 2 5 5 7.5 7.5 7.5 10 10
Hrs. Exp. 2 2 3 2 3 2 2 2 2 3 2 3
6" Flower Pot
14" Flower Pot